

# **The Interaction of the Throughflow with Small Scale Variability**

Janet Sprintall  
Scripps Institution of Oceanography, UCSD  
9500 Gilman Drive  
La Jolla CA 92093-0230  
Phone: (858)822-0589 fax: (858)534-9820 email: [jsprintall@ucsd.edu](mailto:jsprintall@ucsd.edu)

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## **LONG-TERM GOALS**

The long-term goal of this award is to understand the processes that control the generation, evolution and distribution of small-scale, time-dependent features within straits, and how these features interact with the large-scale sub-tidal throughflow within which they are embedded. The effort will focus on a multi-year time series from an ocean sensor array of moored ADCP and temperature-conductivity sensors, and pressure gauge observations in the internal straits of the Philippine seas. The aim is to characterize the spatial and temporal variability of the small-scale features and how they may vary seasonally to interannually as the remote and local (monsoonal) forcing changes. We wish to understand the relative roles of the tidal signal within the straits, as well as the large-scale currents that may flow from the boundaries through the archipelago, in generating and maintaining the major flow features within the straits. Ultimately, this will enable a better representation and prediction in numerical and theoretical models of the structure and evolution of the small-scale features common to sea straits, including their time-dependent variability.

The original proposal was entitled "The Interaction of the Indonesian Throughflow with smaller scale variability in Lombok Strait" and reflected the original Indonesian site for the DRI "Characterization and Modeling of Archipelago Strait Dynamics". The site was re-located to the Philippines in late 2006.

## **OBJECTIVES**

The goal of the ocean sensor array is to improve our understanding of the oceanographic processes that lead to small-scale variability in the flow structure of straits. Specifically, the main objectives are:-

1. To examine the relative roles of the tidal and longer timescale flows in the generation and evolution of the small-scale dynamical flow features in straits,
2. To determine how the small-scale features evolve with observed across- and along-strait variation in sea-level and the corresponding strength and direction of the mean flow,
3. To identify how the small-scale flow structures and sea-level variability may be modulated by both the remote and the local forcing, particularly in response to the seasonal reversal in the monsoon winds.

## **APPROACH**

As part of the "Characterization and Modeling of Archipelago Strait Dynamics" DRI, an ocean sensor array of moorings and pressure gauges were deployed within the straits of the Philippine archipelago.

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Having an array of moorings and pressure gauges within these straits, that resolves both the along-strait and the cross-strait variation in flow and properties, enables us to observe any possible localized or isolated response in the circulation patterns related to the mesoscale and submesoscale processes. The moorings consist of bottom mounted ADCPs and discrete Temperature-Salinity sensors. Upward-looking ADCPs will provide direct velocity measurements of the whole water column within the expected more active flow path of the strait. SBE37 Microcat CTDs with pressure sensors will be scattered along the mooring chain to resolve the stratification. The pressure gauge array will help resolve the sea level signal associated with the tidal forcing (to assist with the validation of the barotropic tidal models) and long planetary waves at the boundaries of the Philippines seas. SBE37 CTDs co-located with the shallow pressure gauges will also add some information on surface temperature and salinity variability. The moorings will provide direct measurements of the velocity, temperature and salinity at sampling rates of  $\sim 0.5$  hours, while the Paroscientific quartz pressure sensors return high precision (0.3 mbar) data with sampling periods of seconds to accurately resolve the tidal flow and changes in sea level (pressure) along and across the strait.

The ocean sensor array was constructed and assembled by engineers and marine technicians at the Scripps Institution of Oceanography (SIO) Hydraulics Laboratory, under the guidance of Senior Development Engineer Mr. Paul Harvey.

It is envisaged that the ocean sensor array will also provide temporal context for the “synoptic” shipborne flow and property measurements, as well as ground-truthing of high frequency radar and SAR images for other DoD funded researchers of the ONR DRI program, “Characterization and Modeling of Archipelago Strait Dynamics”. The high-frequency time series data will also provide a test for evaluating and refining of models and their predictions that are not possible from shipborne observations alone. This will enable a better representation and prediction of the structure and evolution of the small-scale features.

## **WORK COMPLETED**

Three bottom-mounted ADCP moorings were deployed in South Mindoro Strait (sill depth  $\sim 580$  m); Dipolog Strait ( $\sim 480$  m); and Surigao Strait ( $\sim 166$  m) during the Exploratory Cruise in the Philippines Seas in June-July 2007. The South Mindoro mooring was deployed initially for a three-week period, recovered and velocity data downloaded, and then redeployed at the end of the cruise.

During the latter part of this fiscal year we have been busy with mooring design and preparation for the Joint U.S. – Philippines cruise planned on the R/V Melville in November-December 2007. The South Mindoro, Dipolog and Surigao moorings will be recovered ( $\sim 5$  months of data), and then redeployed during this cruise. In addition, upward-downward looking ADCP moorings will be deployed in North Mindoro ( $\sim 430$  m) and Tablas Strait ( $\sim 300$  m) during the cruise. Sprintall and Marine Engineer Harvey will participate in this cruise. All moorings will be recovered during the IOP recovery cruise in January 2009.

The shallow pressure gauge array of six gauges will be deployed with the help of University of the Philippine colleagues (Drs. Cesar Villanoy and Laura David). Sprintall and her marine Engineer (Paul Harvey) visited the Philippines in July 2007 to help with site selection and instruction on assemblage of the pressure gauges. Identified deployment sites (in collaboration with Cesar Villanoy, U. Philippines and Ewa Jarosz, NRL) are: 1. Southwest coast Mindoro Island; 2. east coast Calamian Island group; 3. northwest coast Panay Island (collocated with HF radar); 4. southwest coast Panay

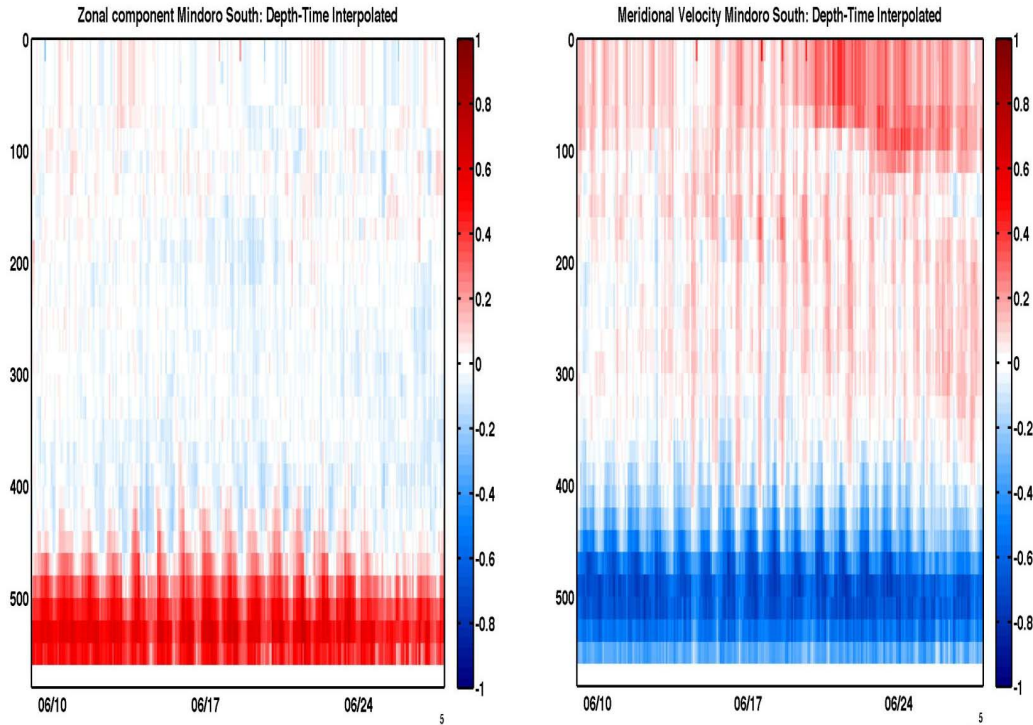
Island (collocated with HR radar); 5. southwest coast Apo Island (Bohol Sea); 6. southwest coast Guian Samar Island (Pacific boundary). The sites 3 and 4 on Panay Island were deployed by our Filipino colleagues in ~August 2007. Our Filipino colleagues will turn-around the pressure gauges in ~ January 2008 with final recovery in ~ January 2009.

## RESULTS

The three-week mooring deployment at South Mindoro shows an exceptionally vigorous benthic layer (Figure 1). The flow in the lower 100 m is consistently directed toward the southeast, the along channel direction, and suggests a strong spill-over into the Sulu Sea. The zonal flow component (Figure 1a) is maximum ( $\sim 0.7 \text{ ms}^{-1}$ ) at the sea floor, whereas the meridional component (Figure 1b) is maximum ( $\sim 0.8 \text{ ms}^{-1}$ ) around 50 m above the sea floor. It is speculated that this difference is related more to the bathymetric effects due to the deepening of the southern bank of the channel rather than bottom friction effects.

In the surface layer, the flow is primarily meridional, and intensifies in the upper 100 m during the later part of the deployment period as the south-eastward winds of the summer monsoon begin to strengthen.

On tidal time scales, the diurnal and fortnightly tides clearly dominate.



**Figure 1: Zonal (left) and meridional (right) velocity from the mooring deployment from 9-27 June 2007 in South Mindoro Strait, Philippines. Strongest flows are found in the bottom 100 m.**

## **IMPACT/APPLICATIONS**

The high-resolution time series data can be used to test the veracity of numerical models of the Philippine region, with obvious application to other archipelago straits characterized by small-scale processes. In particular, the site selection of the pressure gauge component of the ocean sensor array has been designed specifically to provide sea level data to help validate the barotropic tidal model before the IOP begins (PIs: Blaine and Jarosz). Typically many of the available models resolve the narrow straits with only a few grid points, thus providing little spatial information about the internal dynamics and local complexities that occur on short time scales. The high-frequency time series observations will provide a test for evaluation and refinement of all models and their predictions that are not possible from shipborne observations alone. This will enable better representation and prediction of the structure and evolution of the small-scale features such as internal waves, sidewall eddies and separation of filaments, including their time-dependent variability in a region that has few previous subsurface oceanographic measurements.

## **RELATED PROJECTS**

An expansion proposal (N00014-06-1-0690, Modification Number P00003) entitled “A pressure gauge array for observing sea level variability within the Philippines Seas” was funded in April 2007 in order to fulfill the need to expand the pressure gauge array within the Philippines Seas as directed by the DRI.

A DURIP proposal (N00014-06-1-0814) entitled “An ocean sensor array to detect small-scale variability” was awarded in March 2006 that funded the instrumentation and hardware for the project.